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Computer Vision based Measuring Machine

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Abstract – *The aim of this case study is to understand the difficulties faced in the manufacturing industry while quality check is under consideration and finding solutions in order to make the process faster and more efficient. This document is based on "Computer Vison based Measuring Machine". The Machine as whole is designed and manufactured with all the required Arduino Programing and Computer Vision programming by the author himself. The aim of this project is to make a low-cost vison measuring machine which assures better quality inspection results in MSME's for smaller parts.*

***Key Words*: Computer Vision, Machine Learning, Meteorology, Vision Measurement, Image Processing**

1. INTRODUCTION

Computer Vision is the most promising upcoming technology for precision measurement. Many industries cannot perform a complete quality check of the batch manufactured because of the high volume of the manufactured parts causing some of the defective parts to slip through the inspection and shipped ahead. Here, in this stage a computer vision-based program can be deployed which can identify the dimension much effectively than a human being on work

Computers are designed to complete the assigned task more precisely. Using algorithms to complete a particular task can amplify the performance. Machine vison technology can be widely used in many sectors such as automotive industries, Electrical industries. The Computer Vision techniques are actively researched to introduce automation and reduce cost.

Performing a task manually, we can't achieve faster results and also there are time restrictions for humans working in shifts in any industry, also fatigue comes under consideration as humans are not able to perform a same task consistently with same effectiveness. Factors such as distraction, mental health, etc. can affect the performance of humans

For example, while taking measurement of a particular part, factors such as instrument calibration, part holding position, measuring device holding position, knowledge of the worker using the instruments affect the over-all result of the inspection.

Although computers algorithms once deployed can work on continuously without taking any breaks as they don't have any time restrictions. Currently computer-based measuring machine used are VMM's (vision measuring machine) and CMM's (co-ordinate measuring machines) which both requires basic knowledge of the working of the machine itself in order to generate a reliable output and also the cost of these machines are very high.

The aim of this project is to develop an economical machine which can detect the object place on its base and can instantly display the measurements on the computer screen once the program or the application is deployed

2. WORKING STRUCTURE OF THE MODULE

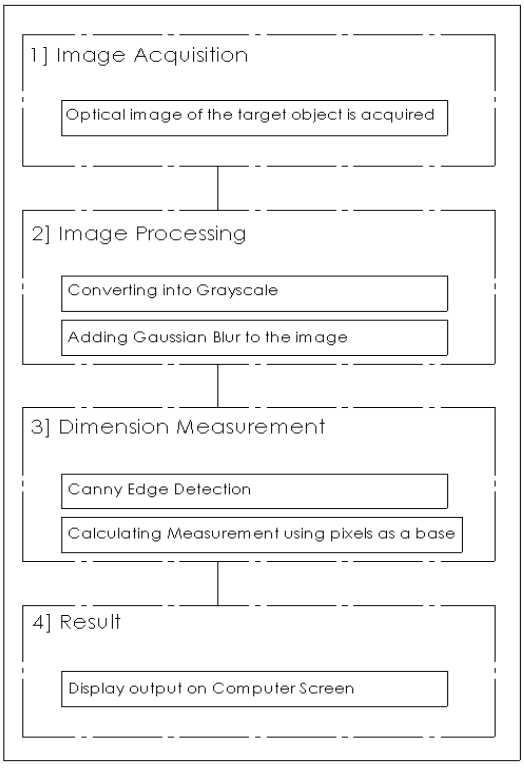


Figure 1- Working Structure

Working of Computer Vision machine is composed of three parts – Hardware system, Software system and Electronic system. The Hardware system mainly concentrates on image acquisition whereas Software system concentrates on image

processing and calculating the dimensions of the target object. Electronic system acts as bridge between both

The flow chart in Figure 1 shows how the process for the measurement is carried out

2.1 Hardware System

Hardware System comprises of components like: Vertical frame, base, frosted acrylic glass, holding clamps, leveling pads

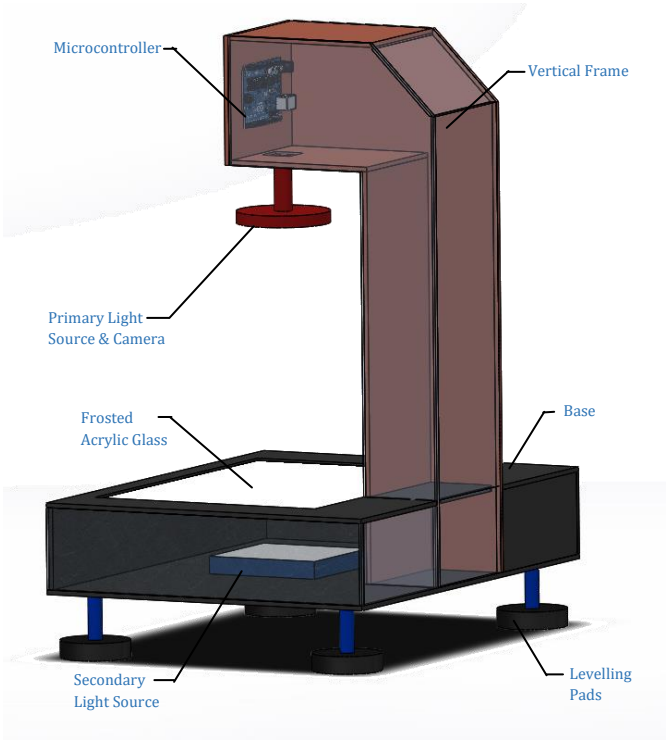


Figure 2 – 3D Model of Hardware

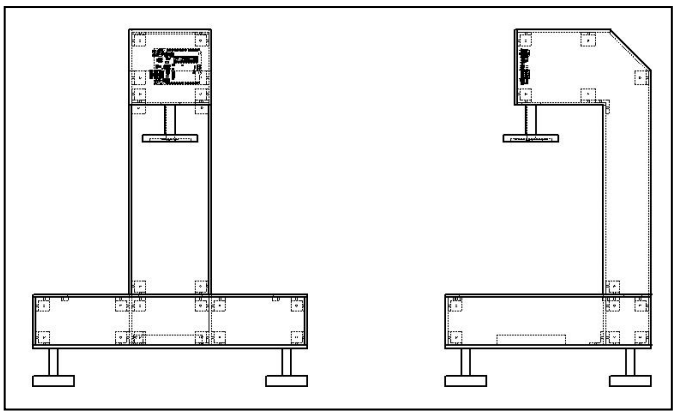


Figure 3 – 2D Drafting of model

Figure 2 & figure 3 shows the assembly of the hardware components with light sources, electronics and all the support brackets. Here the vertical alignment of the camera to base is very important as there should be no shadow

2.2 Software System

Software System is responsible for collecting optical data of the target object, implementing image processing techniques which are converting image into Grayscale, adding Gaussian Blur to the image for smooth edges, Canny edge detection

Using this data and comparing it with the pixels in the image acquired dimensions of the target object is calculated and the result is displayed on output screen. [1]

2.2.1 Image Acquisition

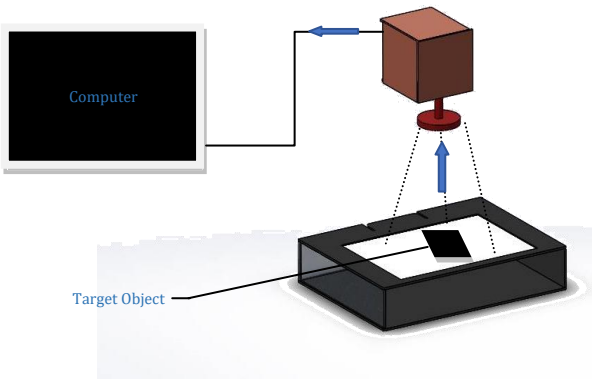


Figure 4 – Image Acquisition

The measurement system captures the image of the target image in RGB format through a WIFI camera module connected to a microcontroller

2.2.2 Image Processing

Image processing comprises of 3 major steps which are image RGB to Grayscale conversion, adding Gaussian Blur to the image and Edge detection.

The image captured from the camera is in RGB format. The color of each pixel is defined by the different values of R (red), G (green) and B (blue) ranging from 0 to 255, by varying these values we can easily recreate any pictures digitally. The size of the image captured is 32 bits But the measurement of the target object size is directly related with the edge detection of the image detected. As for this project the image processing carried out can be conducted with only edge detection, we don't require the huge amount of byte data from RGB as in Grayscale we can still detect the edges by evaluating the brightness of the pixel that to with high processing speed. Thus, the image captured by the camera is first converted to grayscale.[2]

This image needs to me smoothened in order to get proper edge detection. Thus, Gaussian Blur is introduced on the image which makes the edges smooth

To detect the edges of the target object Canny Operator Edge Detection is used. Canny edge detection algorithm method calculates the gradient size and direction of each pixel in the processed image. [3] Using this edge detection algorithm, we can identify the type of contour the target object has. The image processed is also warped to get cleaner images.[4] Result in Figure 5

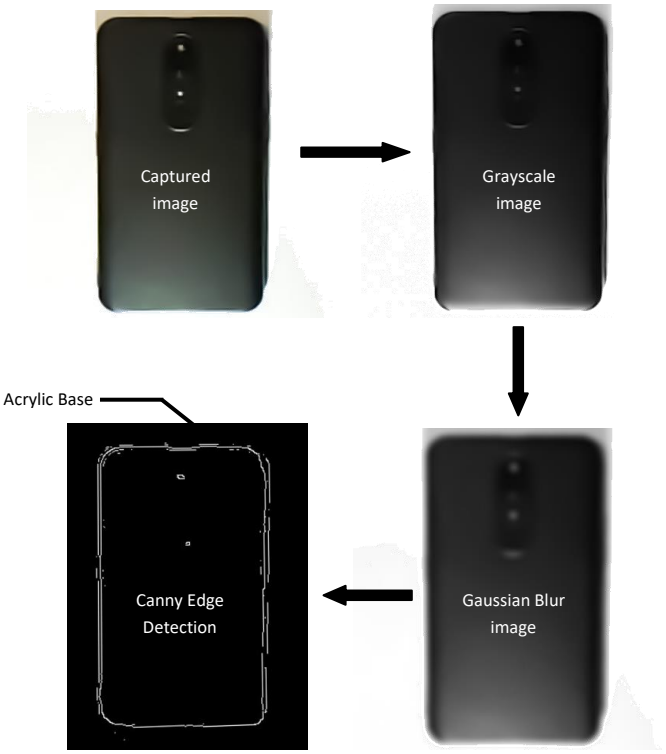


Figure 5 – Image Processing

2.2.3 Measurement

After completing the Image Processing, the obtained image of the target object can be easily measured by calculating the pixel values against the base which is pre-determined and calibrated. The measured value can be converted to desired unit using basic mathematical conversion for millimeters, centimeters, inches, etc. [5]

Figure 6 - Measurement

Figure 6 shows the final result after the measurement process

2.2.4 Calibration

The digital images collected from the computer vision system are the size relationship between the target objects and the base of the machine. But this size relation is in pixels. In order to obtain the specific geometric size of the target object, the relationship between the position of pixels of the target image and the calibrated base must be established. This process is termed as calibration of the system. Basically, the width and height of the acrylic base must match the width and height specified in the program, as the largest contour detected (which in our case is the acrylic base) is the parent dimension according to which the dimensions of target objects would be calculated by the program. [1]

2.3 Electronic System

Electronic system acts as a bridge between the mechanical hardware and computer software. It mainly comprises of 3 components Microcontroller, WIFI Cam module and battery

Light Sources are also used in order to get proper edge detection. There are 2 light sources one on camera mount and another one at base lighting up the frosted acrylic glass plate. [6]

3. LITERATURE SURVEY

Larry Roberts is commonly accepted that the father of the Computer Vision, who in his Ph. D. thesis (Cir. 1960) at MIT discussed the possibilities of extracting 3D geometrical information from 2D perspective views of blocks. [7]

Computer vision began in earnest during the 1960s at universities that viewed the project as a stepping stone to artificial intelligence. Researchers in early stage were too confident in how this technology used with machine learning and artificial intelligence would transform the world as we

see. Soon Computer Vision was being used in many applications and sectors. [8]

Computer Vision based Measurement is being used in industries for past few years now, but the machines developed are of higher industry standards and thus are costly which does not allow small scale industries to invest in such products. The aim of this project is to develop a low-cost measurement system which is efficient and can be used in any atmospheric surroundings

It uses a micro-controller interfaced with a WIFI camera module which sends the optical data to the computer software, where the data received is processed, analyzed, calculated using algorithms and finally displays the output in a very user-friendly way.

High end no-contact measuring machines available in the market require knowledge of its software, for which training is required of the employees and troubleshooting is difficult. On the other hand, this project allows anybody to use the software easily and also allows further development too if required and troubleshooting is easy as there are less electronics involved

4. COMPONENT AND MATERIAL SELECTION

Component selection was done keeping the cost effectiveness as a major concern and also compression was done to find out the most effective one

Material Selected to build the body or the hardware of the machine is chosen to be PLA plastic as they are durable and also easily machinable in order to shape them in required shape and dimensions.[9]

Clamps Used to hold the frame together are selected to be aluminum as it possesses good strength and is light in weight which makes the machine easy to move and thus increasing usability and portability.[10]

Base of the machine where the target object is to be placed should be semi-transparent so as to pass the light, hence frosted Acrylic glass is selected for this component. It needs to be frosted as we don't want the camera to lose its focus from the target object which will give is poor results in Edge Detection algorithm. [11]

Light Sources are selected to be as LED as they consume less power and emit more light. A ring light is selected for the top light source as it will distribute the light evenly around the object resulting in zero shadow condition. [12]

4.1 Camera Modules

Parameters	SSID Camera	ESP32 Wi-Fi CAM	Ras Pi CAM
Cost	15,000/-	700/-	2,000/-
Image Quality	Wide Angle	Moderate	High
Wi-Fi Connectivity	Self-included non-programable	Programable	Programable
Programmable	No	Yes	Yes
Ease of development	No	Yes	Yes
Flexibility	No	Yes	Yes
Accessibility	Difficult because of separate operating buttons	Accessible	Accessible

From the above table we can make out that SSID camera or the camera available in the market are highly costly and also can't be programmed as their software is not open sourced and does not allow connecting to external Wi-Fi. Whereas ESP32 Wi-Fi CAM and Rap Pi CAM are both programable and can be used for development as their program can be written by anyone. They have difference only in image quality and the price. As we do not require very wide-angle image because we are going to further do image processing, we can select ESP32 and Ras Pi as for the camera modules. Here as we are making the project compatible with Arduino, we are selecting ESP32 Wi-fi CAM. [13][14][15]

Figure 7 – ESP32 Wi-fi CAM Module

4.2 Microcontrollers or Microprocessors

Raspberry Pi 3	Arduino UNO
Quad Core 1.2GHz Broadcom BCM2837 64bit CPU. 1GB RAM. BCM43438 wireless LAN and Bluetooth Low Energy (BLE) on board. 100 Base Ethernet. 40-pin extended GPIO. USB 2 ports. Pole stereo output and composite video port. Full size HDMI. Price: 4500/-	Microcontroller: Microchip ATmega328P. Operating Voltage: 5 Volts. Input Voltage: 7 to 20 Volts. Digital I/O Pins: 14 (of which 6 can provide PWM output) UART: 1. I2C: 1. SPPI: 1. Analog Input Pins: 6. Clock Speed: 16 MHz Wifi Enabled with attachments Price : 500/-

From the above table we can make out that Raspberry Pi is over qualified as per the requirement as heavy calculation is to be done on Computer itself and also it increases the cost, Whereas Arduino UNO is suitable for the project. [16][17]

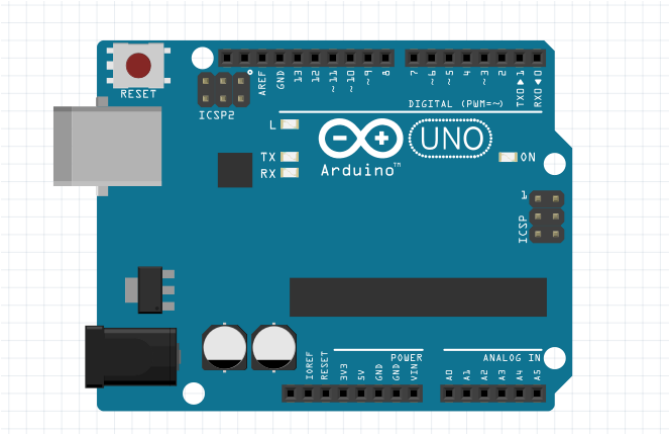


Figure 8 – Arduino UNO

Battery selected for this project is 5V output Lithium-ion rechargeable battery which is suitable as it can power all the electronic components and also can last a longer period of time for up to 1 day at on condition. [18]

5. Software Libraries Selection

5.1 Python Libraries for Computer Vision

5.1.1 Keras:

Written in Python, Keras is a high-level neural networks library which is capable of running either of the frameworks TensorFlow or Theano. This library was developed with a focus of fast experimentation. This deep learning library provides many features, including support for convolutional networks and recurrent networks, allowing easy and rapid prototyping. [19]

5.1.2 PyTorchCV:

PyTorchCV is a PyTorch-based framework specialized for computer vision tasks. This framework is a collection of image classification, segmentation, detection, and pose estimation models. There are several implemented models in this framework, including AlexNet, ResNet, ResNeXt, PyramidNet, SparseNet, DRN-C/DRN-D, and more. [19][20]

5.1.3 OpenCV:

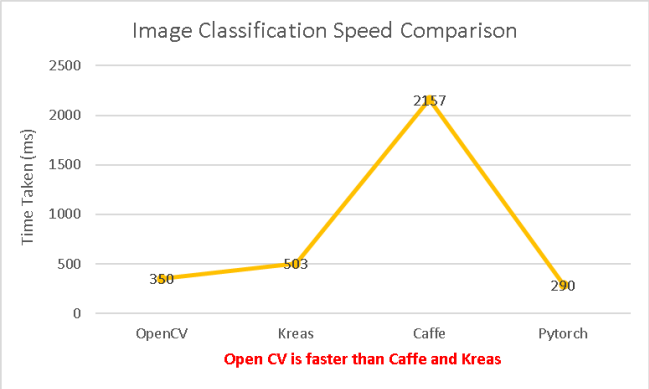
OpenCV is a popular and open-source computer vision library essential for real-time applications. OpenCV library has a modular structure and includes several hundreds of computer vision algorithms. OpenCV consists of a number of modules, including image processing, video analysis, 2D feature framework, object detection, camera calibration, 3D reconstruction and more. [19][21]

5.4 Caffe:

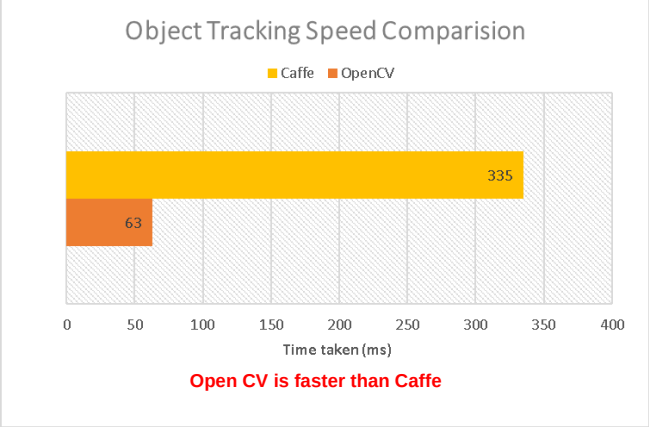
CAFFE (Convolutional Architecture for Fast Feature Embedding) is a deep learning framework, Caffe supports many different types of machine learning architectures geared towards image classification and image segmentation. It helps CNN, RCNN, LSTM and fully connected neural network designs. Caffe supports CPU and GPU- based acceleration computational libraries such as NVIDIA, and Intel MKL, etc. [19][22] Caffe provides a complete toolkit for training, testing, finetuning, and deploying models, with well-documented examples for all of these tasks.

5.2 Performance of different Computer Vision Libraries

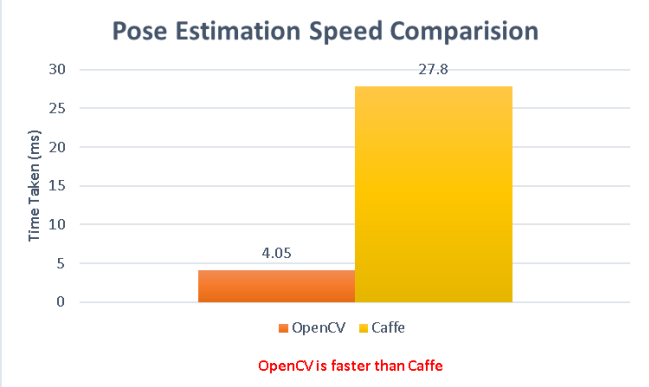
5.2.1 Image Classification



5.2.2 Object Tracking



5.2.3 Pose Estimation



Results show OpenCV is faster and more reliable being open source

5.3 OpenCV:

It is a library of programming functions mainly used for image processing. It provides a de-facto standard API for computer vision applications. Real-time processing allows us to solve many problems using image processing applications.

Image processing is a form of signal processing in which the input can be an image or a video frame, the output is an image or set of characteristics related to the image. OpenCV is a library mainly used for image processing. It is freely available on the open-source Berkeley Software Distribution license. Intel launched OpenCV as a research project. OpenCV library has various tools to solve real time computer vision problems. It contains low level image processing functions and high-level algorithms for face detection, feature matching and tracking. [19]

5.4 Arduino & ESP32 Base Code

Following libraries are used for transmitting the data over a Wi-fi Connection.

#include <WebServer.h>

We can use the web server to serve interactive pages, and to react to certain POST request.[23]

#include <WiFi.h>

This library is used to connect Arduino and ESP32 to internet.
It requires ID and password of the network to be connected with. [24]

#include <esp32cam.h>

ESP32cam library provides an object-oriented Application programming interface to use camera on the microcontroller. In our case we are using ESP32 AI thinker module.
This library is used along with AI Thinker ESP32-CAM board.[25]

6. FUTURE SCOPE

As much research is actively conducted in computer vision, new libraries are continuously introduced and developed. Also, this technology is becoming more accessible and affordable which will help many industries to adopt it as it gives promising result and has high precision performance. This technology further is going to change the shape and working of the industries as we see now, not only in measurement sector but even other emerging automation technologies use Computer Vision for various detection.

7. CONCLUSION

In this paper we have revisited the Cutting-edge technology of computer vision and its application in automation of the industry. This paper provides a detailed information of how collaborating Hardware, Software and Electronics can lead to create intelligent machines which further help in reducing work load and ease of operation with high performance and

less or negligible time restrictions as these machines can run non-stop for a very long period of time.

We have focused on developing an economical computer vision-based Vision Measuring Machine which is done by using Python Algorithms and basic mathematics in order to display the results on the screen.

Here detailed information about the working process is provided with the design of the machine and also looking from software perspective all the libraries are compared with each other to get the best out of them and working of selected library is also explained briefly. Also, the detection of the target object and calculating its dimensions is explained thoroughly.

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9. BIOGRAPHIES

Ashish Karigar, Final year B. Tech Mechatronics Student currently studying in **Symbiosis skills & Professional University (SSPU)**, Pune, has a knowledge in CAD 3D modelling and has certification in Machine Learning and Python Programming language and has worked on various computer vision project

Dr. S. S. Sonavane had completed PhD (Electronics Engg.) from IIT, Dhanbad in 2009. He is having 23 years of experience in educational field & served for 12 years as Director in many well-known organizations such as DY Patil Technical Campus, Pune. Currently he is working as 'Director' at School of Mechatronics Engineering of Symbiosis Skills & Professional University (SSPU), Pune.